

Lincoln Space Surveillance Complex (LSSC) Modernization

**T. L Sangiolo,
MIT Lincoln Laboratory**

1. Introduction

Lincoln Laboratory has embarked upon a project to modernize the Radar Systems (ALCOR, MMW, TRADEX and ALTAIR) in the Kwajalein Missile Range (KMR) utilizing Radar Open System Architecture (ROSA). This program is called KMR Modernization and Remoting (KMAR). Lincoln Laboratory has already delivered and successfully integrated the ALCOR and MMW radars. Recently, another group at Lincoln Laboratory was exploring ways to modernize the three LSSC radar systems (HAY, HAX, and Millstone (MHR)). Since the two efforts were similar, it became apparent that sharing knowledge and resources would be beneficial to both. It was further recognized that making these systems to be as closely identical as possible would result in more benefits for Lincoln Laboratory and the government.

This approach reduces duplication of efforts, maximizes the efficiency of using human resources across all areas of radar development, and provides a way to use LSSC radars as a radar test-bed, in close proximity of Lexington, where new designs could be implemented and tested prior to shipping them to Kwajalein. This has turned out to be a perfect example of transferring technology from multiple radar systems to the development of a new radar system. The paper describes the use of improved common hardware architecture and common core software system to implement a broad modernization project that will eventually cover seven radars. This commonality will be followed in the future to streamline the maintenance of these radars. “Open Systems” and “Commercial-Off-The-Shelf”(COTS) are defined by their respective source by the following for all to have a consistent interpretation of their use in this document.

- **Open Systems (DOD/SEI)**
“An open system is a collection of interacting software, hardware and human components, designed to satisfy stated needs, with the interface specification of components fully defined and available to the public, maintained according to group consensus and in which the implementation of components are conformant to the specification.”
- **COTS (summary from Federal Acquisition Regulations)**
 - **Customarily used for nongovernmental purpose and has been sold, leased or licensed to the general public**
 - **Exists a priori (in a catalogue or price list)**

The use of ROSA has increased the capabilities of the LSSC radars. This has enabled the HAX and HAY radars to participate in additional Lincoln Laboratory programs. The Wideband Network Systems (WNS) and the Photonic A/D Converter Technology (PACT) System are two programs that have been spawned, and the consolidation and remote operations of the LSSC radars have just started.

REPORT DOCUMENTATION PAGE

Form Approved OMB No.
0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 03-04-2001	2. REPORT TYPE Conference Proceedings (Papers)	3. DATES COVERED (FROM - TO) 03-04-2001 to 05-04-2001		
4. TITLE AND SUBTITLE Lincoln Space Surveillance Complex (LSSC) Modernization Unclassified		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Sangiolo, T. L. ;		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME AND ADDRESS MIT Lincoln Laboratory 244 Wood Street Lexington, MA02420-9108		8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS Lincoln Laboratory Massachusetts Institute of Technology 244 Wood Street Lexington, MA02420-9108		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT APUBLIC RELEASE ,				
13. SUPPLEMENTARY NOTES See Also ADM001334, Proceedings of the 2001 Space Control Conference (19th Annual) held in Lincoln Laboratory, Hanscom AFB, MA on 3-5 April 2001.				
14. ABSTRACT Lincoln Laboratory has embarked upon a project to modernize the Radar Systems (ALCOR, MMW, TRADEX and ALTAIR) in the Kwajalein Missile Range (KMR) utilizing Radar Open System Architecture (ROSA). This program is called KMR Modernization and Remoting (KMAR). Lincoln Laboratory has already delivered and successfully integrated the ALCOR and MMW radars. Recently, another group at Lincoln Laboratory was exploring ways to modernize the three LSSC radar systems (HAY, HAX, and Millstone (MHR). Since the two efforts were similar, it became apparent that sharing knowledge and resources would be beneficial to both. It was further recognized that making these systems to be as closely identical as possible would result in more benefits for Lincoln Laboratory and the government.				
15. SUBJECT TERMS				
16. SECURITY CLASSIFICATION OF: a. REPORT Unclassified		17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 8	19. NAME OF RESPONSIBLE PERSON Fenster, Lynn lfenster@dtic.mil
b. ABSTRACT Unclassified				19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007
Standard Form 298 (Rev. 8-98) Prescribed by ANSI Std Z39.18				

The WNS program is a high-speed network demonstration utilizing simultaneous operation of the HAY and HAX radars. Both radars will simultaneously track the same LEO satellite with a wide bandwidth waveform and transmit their radar signature data over an ultra high speed fiber network to Lincoln Laboratory where in real-time images will be generated. The ability to be able to transmit radar data over the high-speed fiber optical network at rates in excess of a Gbit/sec is the purpose of the demonstration.

The PACT system is a technology demonstration of moving the radar digital sampling closer to the front-end of the receiver chain, preserving all of the signal bandwidth without correlation mixing. With the ROSA architecture the received signal is mixed down through three mixing stages to 20MHz with 18MHz of bandwidth. The PACT technology initially will optically sample the Principal Polarization Channel at 1.38GHz with 31.5MHz bandwidth. Future plans include sampling all four channels at the same 1.38GHz but increasing the bandwidth to 252.5MHz.

2. Radar Open System Architecture (ROSA)

Radar modernization with ROSA encompasses an entire radar system with the exception of the antenna and its associated motor drive electronics, the transmitter electronics, and the RF portion of the receiver. A simplified block diagram of the KMAR ROSA Architecture is illustrated in Figure 1 and depicts what has been modernized by color. Figure 2 illustrates how ROSA is configured as a distributed processing system. Having a distributed processing system has many advantages including the following:

1. Reduced development time and O&M cost
2. Decomposition provides efficient use of engineering resources.
 - Allows many small development teams (distributed locations)
 - Allows for concurrent integration, test and evaluation
3. Components easily added, shared and modified
4. Migration to new technology can be done at the unit level
5. New developments can begin with working components
6. Better acquisition model, reduced NRE
7. Subsystems encapsulate specific radar function
8. Underlying hardware and software is hidden
9. Subsystem components completely define their functionality and interfaces to the outside world

Radar Open Systems Architecture - ROSA

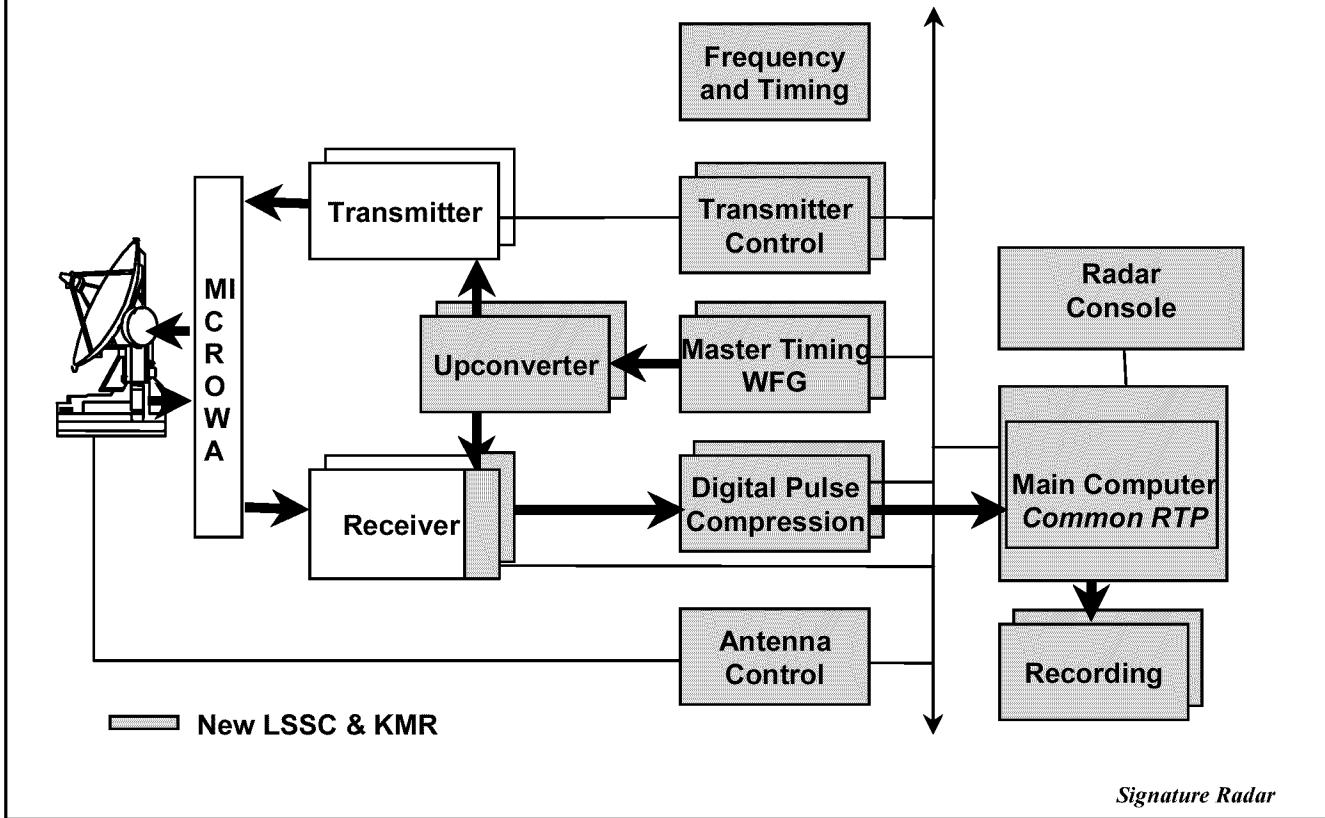


Figure 1 – Simplified Block Diagram of ROSA

What makes ROSA unique is that its primary architecture consists of all Commercial-Off-The-Shelf (COTS) interfaces and components. Each ROSA subsystem is comprised of an identical four-board COTS set:

1. Motorola 604– Power PC Single Board Computer (SBC)
2. Systran - Reflective Memory Interface (PMC connection to Motorola 604)
3. True Time - Time of Day Clock
4. SBS Greensprings Board for Power Supply monitoring

The communication between all of the subsystems is accomplished by the use of the COTS Systran Reflective Memory. This allows the control parameter distribution of tasks throughout subsystems and the main Radar Computer. This facilitates program development by decomposing the system.

The other major characteristic of the KMAR ROSA system is that it utilizes a common core real-time program (RTP) for all of its radars. Each sensor has unique configuration files that contain sensor specific characteristics. For the LSSC modernization, two major software modules had to be incorporated into the “Core RTP”: Debris for HAY and HAX and deep space tracking for Millstone.

The ROSA architecture lends itself readily to adding additional subsystems. For example, if there are additional range windows needed then an additional Receiver Subsystem and Digital Sampling Subsystem

could be added. If the additional range window needs independent control then an additional Timing Subsystem could also be added. The system is very flexible as the following figures 2 thru 5 illustrate.

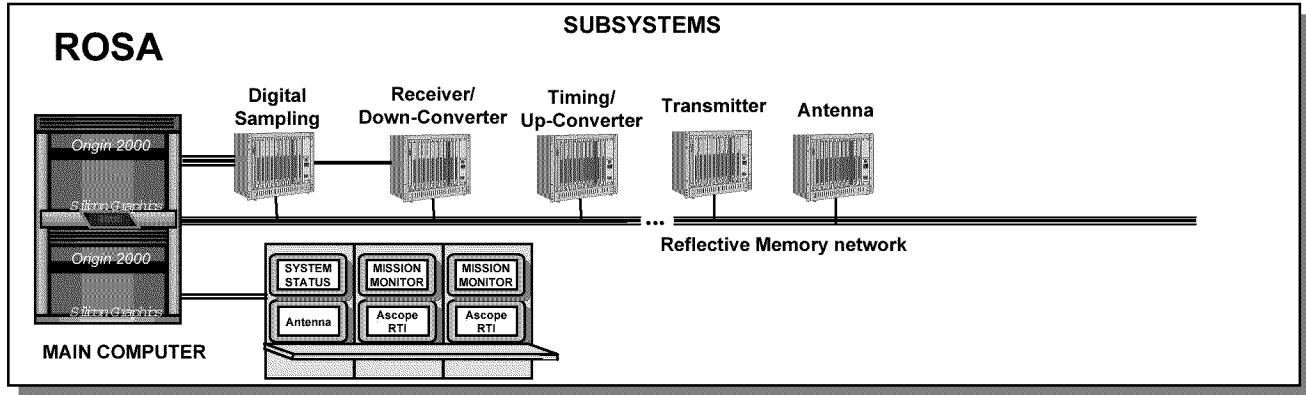


Figure 2 - KMAR ROSA Architecture

The HAY/HAX Radar Process and Control System Architecture with ROSA is illustrated in Figure 3 and in Figure 4 after the WNS system is integrated. As Figure 4 illustrates the two Radar systems are identical with the exception of their respective Radar characteristics. The green solid and green/gray shading are the WNS system additions and the gray are the post modernization hardware prior to WNS.

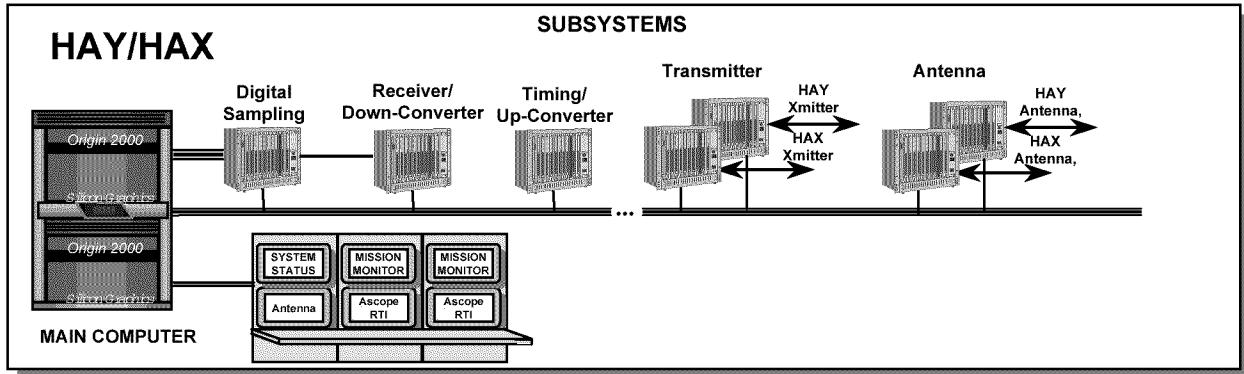


Figure 3 - HAY/HAX Radar ROSA Architecture

HAX/HAY ROSA – WNS Block Diagram

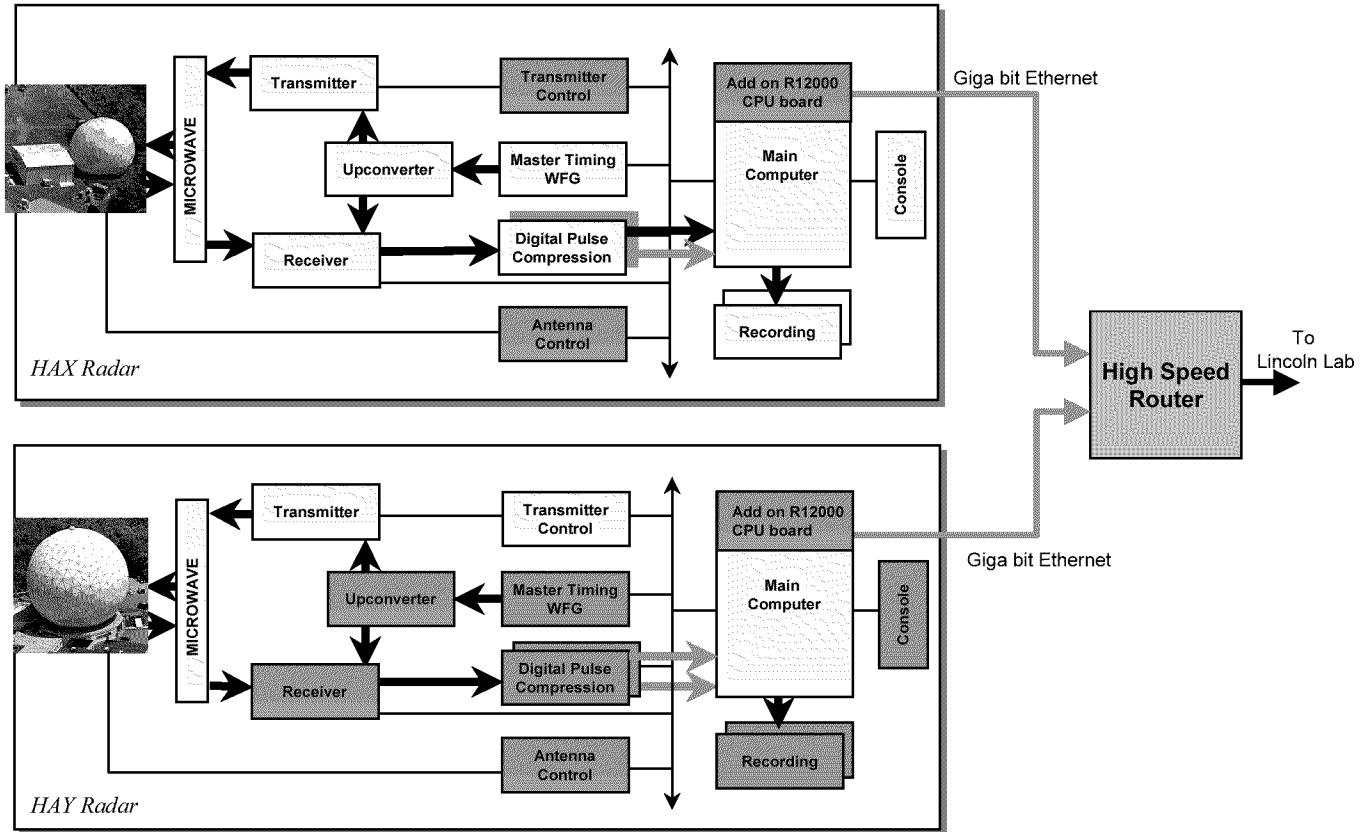


Figure 4 – HAY/HAX WNS Block Diagram

The Millstone ROSA implementation is illustrated in Figure 5. This system has a combined Timing and Transmitter subsystem.

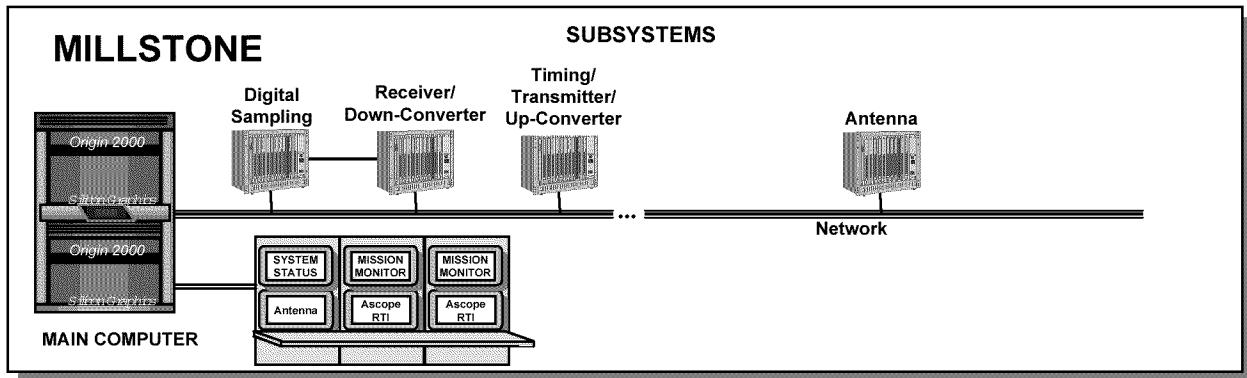


Figure 5 – Millstone Hill Radar ROSA Architecture

3. Waveform Generation an example of modernization

Currently the HAX and HAY radars use wide bandwidth (2 GHz and 1 GHz respectively) linear FM pulse waveforms for data collection. There are two Waveform Generators utilized in the existing system a Narrowband and a Wideband Generator. The Narrowband Generator is utilized in pulsed continuous wave (CW) and narrow bandwidths (NB) of up to 10MHz. It is also used in wideband (WB) waveforms to correct for Doppler during receive time due to the fixed waveform generated by the Wideband generator. The wide bandwidth linear FM waveforms are generated using a voltage-controlled oscillator that is phase locked to the system reference frequency. This technology dates back to the original ALCOR 500MHz-bandwidth waveform generator developed in 1967. This system with both ramp generators and associated equipment is contained in four 19inch racks.

The Wideband linear FM pulse is generated for a fixed pulse duration of 256 :s. This is restrictive in that it limits the pulse repetition frequency (PRF) of the radar because of their duty cycle limitations. In the case of HAY and HAX these are 35% and 30%, which translates to a PRF of 1367, and 975 respectively. Parameters of the current waveform and clock pulse generators are the following:

- **Digital Narrow Band Waveform generator**
 - Supports CW, NB and WB Modes
 - F_0 10MHz, Bandwidth $\pm 1.25\text{MHz}$
- **Analog Wide Band Waveform generator**
 - WB Mode Only
 - Fixed 256 μsec Pulse Width
 - F_0 6GHz, Bandwidth $\pm 512\text{MHz}$

The replacement waveform generators used in the ROSA system for ALCOR and MMW are COTS Direct Digital Synthesizers (DDS). For the LSSC radar systems and for ALTAIR and TRADEX, these units have been replaced with a Lincoln Laboratory designed medium bandwidth DDS. These units are located in the Master Timing Subsystem (MTS) and develop parameter controlled linear FM chirps and pulse-widths that are used in all modes of operation. There is a separate waveform generator for transmit and receive. Having independent generators allows dynamic test target capability utilizing the transmit waveform generator as a correlation source at receive time driven from an independent test target file.

Control parameters to the DDS (Starting Frequency, Slope, Starting Phase and pulse-width) are sent from the MTS control computer via the Versa Module European (VME) bus. As with its predecessor, the output of the digital waveform generator is frequency translated and multiplied to the appropriate transmit and receive frequencies. Characteristics of the ROSA Waveform Generators are the following:

- **Raytheon (Hughes) COTS VME Digital Waveform Generator (for ALCOR and MMW)**
 - Supports all waveforms CW, NB and WB modes
 - 960 MHz clock frequency – 128 MHz Bandwidth
 - Variable pulse duration
 - Waveform list generation
- **Lincoln Lab VME Digital Waveform Generator**
 - Supports all waveforms CW, NB and WB modes
 - 320 MHz clock frequency – 64 MHz Bandwidth
 - Variable pulse duration
 - Waveform list generation
 - Phase correction memory
 - Chaotic waveform capability

4. Master Timing Subsystem

The Master Timing System of the LSSC radars generates all of the precise timing signals necessary to control all of the radar subsystems at a pulse repetition interval (PRI) rate. The MTS is comprised of the standard subsystem four board COTS set and three Lincoln Laboratory designed boards.

The three Lincoln Laboratory designed boards are the following:

- The Master Timing System Timing Generator (TG) Board - This board generates the precise PRI, transmit and receive strobes for all PRI controlled subsystems. It provides the fine range control for the Clock Pulse Generator necessary for A/D sampling and parameter control of the DDS. In addition, this identical TG board is utilized in all subsystems that require precise timing generation such as the Receiver, Transmitter and DPCS subsystems. This is accomplished by loading different FPGA files into these subsystems during boot-up time.
- The Clock Pulse Generator (CPG) Board - This board's function is to provide the variable phase 40 MHz clock that is utilized for A/D clocks. The phase resolution of the CPG is 11.25 Picoseconds.
- The Medium Band Ramp Generator (MBRG) Board - This board interfaces directly to the TG start triggers and synchronizes them to its 320 MHz clock to ensure the precise start of its programmed waveform.

ROSA Master Timing Subsystem (MTS)

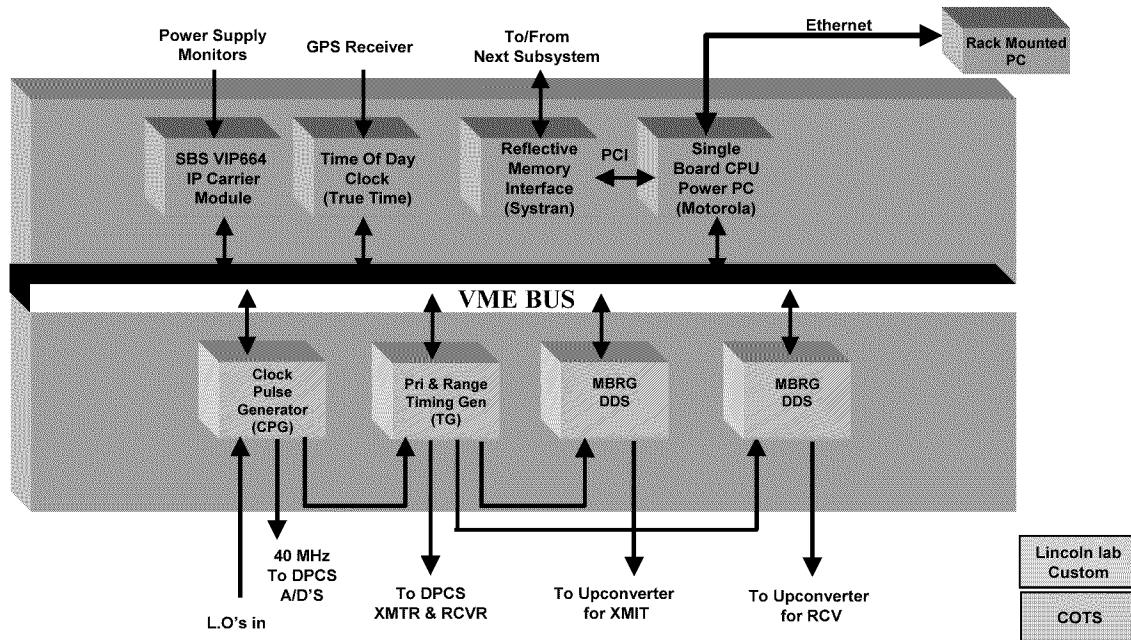


Figure 6 – ROSA Master Timing System Block Diagram

5. Summary

A major modernization is underway for the three LSSC radars HAY, HAX, and the MHR, utilizing the KMAR ROSA architecture. The HAX radar has been fully modernized and is in its validation stage. The HAY radar will enter its validation stage in June of FY01. The MHR modernization is well underway with all system components procured. The WNS system is in process with many of its system components procured. The PACT system has installed its fiber cable between the HAX antenna and the HAY/HAX control room.

The ROSA modernization will provide many new features for the HAY/HAX radars, which include variable wideband pulse-widths for higher PRF's, extended wideband range capability, and the capability of having mixed waveform modes to enhance tracking. The modernization of the MHR will improve its low earth orbit tracking capability as well as having multi-target tracking capability.

With KMAR ROSA technology implemented at LSSC, the three radars could serve as a potential test-bed for future algorithmic and hardware upgrades. ROSA also provides a common hardware and software base for LSSC personnel as well as Kwajalein personnel. Figure 7 illustrates all of the seven Lincoln Laboratory radars that are being modernized with ROSA. Looking at the frequencies and various applications that these radars perform illustrates the flexibility of ROSA both in hardware and software.

The ROSA hardware was recently evaluated to modernize the Eglin FPS-85 Radar. Because of its flexible architecture it lends itself very well for that modernization too. This architecture with its current implementation for the Kwajalein and LSSC Radars spans frequencies of VHF to W Band (95 GHz).

Lincoln Laboratory Modernization Radars *Frequency Bands*

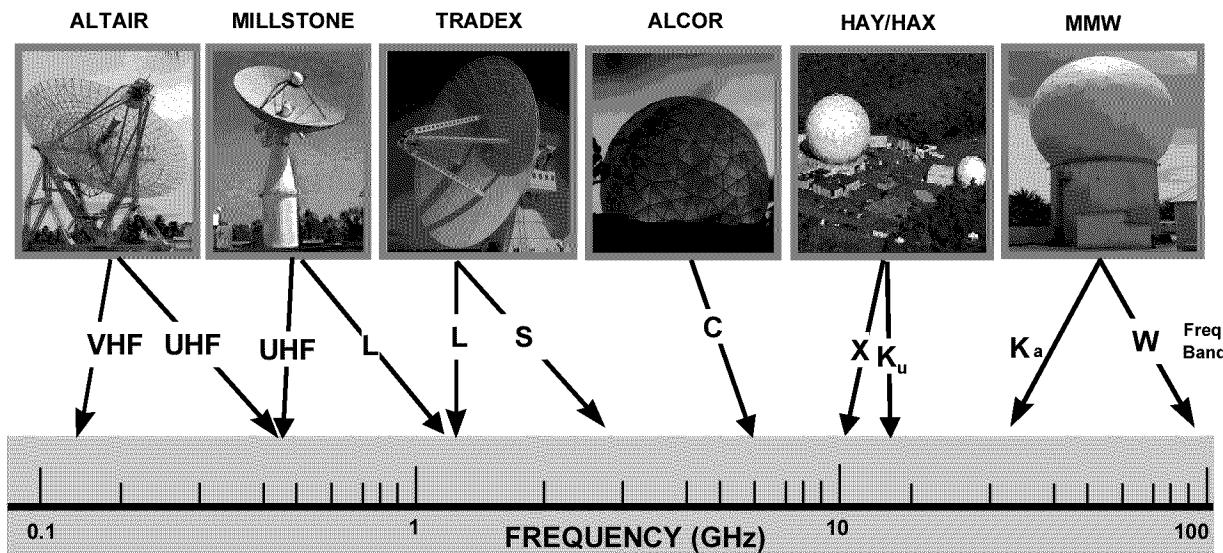


Figure 7 - Lincoln Lab ROSA Modernization Radars